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Development of an independent hydrology audit methodology to support flood risk assessment in the planning process in Scotland

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Abstract

The recent flooding in the North East of Scotland has highlighted issues around climate change due to significant changes in duration, severity and volume of precipitation events. The Planning (PA) and Flood Authorities (FA) often do not have the capacity or resources to review and check the accuracy and robustness of the SUD schemes nor the calculations submitted by developers. This study demonstrates the development and application of an Independent Hydrology Audit (IHA) service aimed at auditing and reviewing 'in principle' planning applications from the aspect of flooding risk to the wider community the development is located within. The output of this service is to establish a more accurate representation of surface water impact from developments through the use of adequate green/blue infrastructure, provide a greater assurance to the communities at risk of flooding, and help the PA and FA meet their statutory obligations at the initial stage of planning.

Keywords: Floods and floodworks; waterways and canals; social impact; town and city planning; sustainability; infrastructure planning; drainage and irrigation

1. Introduction

From a global perspective, the last 30 years have been the warmest since accurate records began over 100 years ago. The period has also been remarkable for the frequency and intensity of extremes of weather and climate. An important indicator of climate change is precipitation. Warming of the Earth's surface causes increased evaporation from both oceans and land, leading to increased atmospheric water vapour and so to increased rainfall. In a warmer world with increased greenhouse gases, average precipitation increases and the hydrological cycle becomes more intense (Houghton, 2009). Hence, in regions of increased rainfall, larger amounts of rainfall will come from increased convective activity and more really heavy showers and more intense thunderstorms, thus increasing the likelihood of flooding.

Increased storm intensity has been followed by the insurance industry over recent years and costs of weather related disasters over the last 50 years have been tracked. There has been an increase in financial losses due to these events by a factor of over 10 in real terms since the 1950s (Houghton, 2009). This is partially due to the growth in population in particularly vulnerable areas, such as residential and commercial development in floodplains and to other social or economic factors. However, a large part is due to increased storminess in recent years (Houghton, 2009).

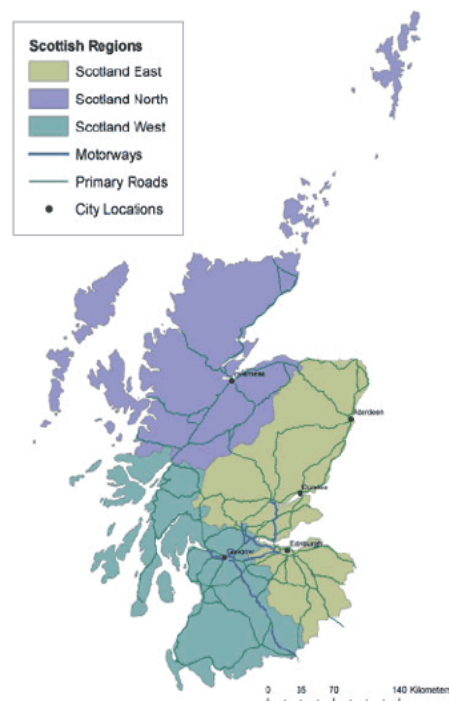


Figure 1: Map of Scotland showing boundaries of the three regions (North, West and East Scotland). Source: SNIFFER (2016)

Urban areas have a wide variety of infrastructures, including not just industrial and commercial buildings and homes, but also power, communications and transport services, water, food and agricultural and healthcare services. The risks from climate changes has impacted these systems in terms of their stability, serviceability and reliability. Weather data collected since 1961 shows that the climate in Scotland has changed significantly over the last 40 years with average temperatures in Scotland having increased by 0.5°C since 1914 (SEPA, 2015). In July 1997, a severe flood in Elgin affected 600 residential properties and 170 commercial properties causing £100 million of damage. Over 1200 people were evacuated. Further flooding occurred in 2009.

Flooding also carries with it increased risk of landslides. In 2007, Scotland experienced its wettest June since 1938. In the autumn of that year, landslides caused by heavy rain brought hundreds of tonnes of mud down on Pennan in Aberdeenshire (SEPA, 2015). Most areas of Scotland have experienced a significant rise in precipitation (Table 1). This is most pronounced in the winter months, with the East of Scotland experiencing a 36.5% increase and the North and West of Scotland both receiving a 67%-69% increase in precipitation over the 1961 levels. These changes clearly have an impact and explain why major flooding and landslides have become more frequent in some parts of Scotland.

Table 1: Changes in precipitation across Scotland since 1961. Source: SNIFFER (2016)

Research by the UK Climate Impacts Programme (SNIFFER, 2016) has predicted that in the coming decades the number and severity of storm events across Scotland could increase, leading to increased risk of flooding. Data collected from rivers already shows a significant increase in river flows over the last 80 years. Scotland has 50,000 km of rivers and 3,425 km² of fluvial flood zone – that's 4.3% of the land area of Scotland. The Scottish Environment Protection Agency (SEPA, 2016) has produced a real time flood map to show the areas at risk of flooding from rivers or the sea. It is estimated that almost 100,000 properties lie in those areas at risk of flooding – approximately 73,300 from rivers and 26,200 from the sea. A total of 3.6% of properties in Scotland are deemed to be at risk from flooding (SEPA, 2016).

Flooding affects our lives in many ways. It can have serious effects on our health and wellbeing, our homes and businesses and the environment. It isolates communities and causes major disruption to transport networks and to vital services. In 2002, the economic cost of flooding in Scotland was estimated to average £31.5 million per year from inland flooding and £19.1 million from coastal flooding (Werrity et al, 2002). The estimated losses arising from the Tay/Earn flood of 1993 and the Strathclyde flood of 1994 are £30 million and £100 million respectively. More

recently, the average annual financial damage attributable to inland flooding was conservatively estimated to be £20 million (Werrity et al, 2007). This value is projected to increase by 27% by the year 2020, 68% by the year 2050 and 115% by the year 2080 due to the effects of climate change.

Another climate change effect that is associated with flooding is the rise in sea levels. Sea level rises ranging from >300mm down to 80mm have been predicted around Scotland's coast by 2050 (Werrity et al, 2007). Results show that, despite the fact that the coastal area at risk from flooding (966 km²) is less than one third of that of inland floodplains (2,950 km²), the number of residential and commercial properties potentially at risk is much higher in coastal areas (93,830) than inland (77,191), reflecting a higher density of settlement and commercial activity (Werrity et al, 2002).

The size and density of the transportation and residential infrastructure, coupled with the fact that they are located in or adjacent to coastal or river floodplains, the difficulty and considerable expense that would be incurred to retrofit or to relocate vulnerable portions of this infrastructure and the need to keep the systems operational are important considerations for climate change adaptation. Both transportation and residential systems have condition and capacity issues, which add to the climate change problem (Zimmerman and Faris, 2010). For example, the lack of maintenance of the aging transportation infrastructure in North-East Scotland, coupled with the capacity of the drainage systems which had not been upgraded to meet the climatic change predictions contributed towards numerous instances of washout, debris and mud flows, slope instability and damage to the residential infrastructure systems (Mickovski, 2014).

The infrastructure systems also have multiple owners and complex sharing arrangements that pose challenges to introducing adaptation. The same applies to the water infrastructure where the aging infrastructure, a complicated regulatory environment and lack of redundancy pose the biggest challenges to climate change adaptation. The infrastructure sectors described above are interdependent (Rinaldi et al 2001) with often complex relationships between each system. It is important to identify and define these relationships in order to manage the risks from the effects of infrastructure failure of any part of the system.

In order to ensure value for a project, it is essential to identify and manage the project risks. All parties involved in a project have a role in ensuring that project risks are identified, reported, overcome or managed. Climate, hydrological, and ground conditions are often uncertain and a risk to any project. The risks from these conditions must be managed in a pro-active manner (Mickovski, 2014). In addition, the socio-economic risk of uninsurable regularly flooded property and the emotional and financial stresses caused by this and by displacement whilst homes are

repaired, are significant (Werrity et al, 2002), and so action plans to protect the vulnerable in society need to be sensitively and efficiently prepared, relative to the risks presented.

The aim of this study is to confirm the need for and to develop an independent hydrological audit (IHA) methodology to support decision making during the planning process in Scotland. The objectives of this study include investigation of the climate change effects for a flood-prone area of Scotland, the current planning process and the duties and responsibilities of the statutory stakeholders in relation to transportation, residential and water infrastructure. Based on experiences in other disciplines and best practice, an outline of the proposed methodology is developed for the initial ('in principle') planning application stage of the project life and demonstrated through case histories for the initial stages of planning.

2. Background

2.1 History of recent flooding in Aberdeenshire

As part of the National Flood Risk Assessment (NFRA), SEPA has identified Local Plan Districts based on river catchments and Potentially Vulnerable Areas (PVA) where there is a risk of flooding. The area of concern for this study covers Stonehaven, which lies in the Aberdeenshire Council area and is part of the North East Local Plan District. This southern part of Aberdeenshire falls within the Tay Estuary and Montrose Basin Local Plan District. The NFRA published in December 2011 identified that the main source of flood risk in the area comes from river and surface water. Coastal flood risk is not seen as significant when looking at the area as a whole.

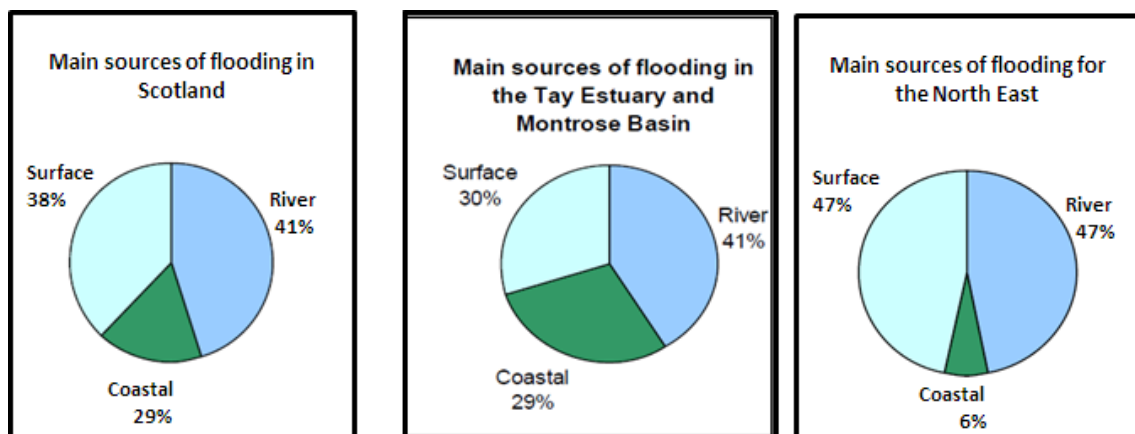


Figure 2: Sources of flooding in Scotland (Aberdeenshire, 2016)

The information for the North East and for the Tay Estuary and Montrose Basin and Stonehaven itself can be compared to information which was gathered through the NFRA for the whole of

Scotland (Figure 2). The PVA are also highlighted and Stonehaven is in one of those areas that has more than 50 properties at risk (Aberdeenshire, 2016).

The North East Local Plan District includes Aberdeenshire Council (AC), Aberdeen City Council, parts of Moray and the Cairngorm National Park Authority and includes 5000 properties that lie in the floodplain. Between 2008 and 2013 there have been some rainfall events that have caused widespread flooding. Several of these have affected Stonehaven. Causes of flooding in Stonehaven during this period (Table 2) were 42% due to coastal flooding, 36% due to river flooding and 22% due to surface water runoff (Aberdeenshire, 2016).

2.2 Flood Risk Management in Aberdeenshire

A number of flood protection schemes have been put into place under the Flood Prevention (Scotland) Act 1961, amended 1997. The Stonehaven Flood Protection Scheme was put forward for public consultation in 2015 and involves carrying out works to reduce the risk of flooding of residential, non-residential and commercial land in Stonehaven by the construction of flood walls and flood embankments along the River Carron and Glaslaw Burn, river bed lowering and raising and replacing bridges over the River Carron with ancillary works to services (Aberdeenshire, 2016b).

Table 2. Historic flooding events in Stonehaven since 2008

The Seventh AC Biennial Flood Report (Aberdeenshire, 2016) identified a range of actions and proposals, including maintenance programmes to reduce the likelihood of flooding, by preference using soft engineering methods, including land forming and creating flood water capacity, unless conditions require different measures. Stonehaven, which sits within the Kincardine and Mearns (North) District, has been subject to a range of these actions of maintenance or minor improvements since 2008 and a recent flood study investigated coastal landslip issues, leading to a flood alleviation scheme being put into place. It is also one of the locations that is recognised to have problems with surface water and is one of the settlements deemed to be at high risk of flooding by AC with three out of the fifteen recent Stonehaven development applications deemed to be at risk of flooding (Aberdeenshire, 2016c).

Stonehaven has a community action group that focuses on flood risk and this forms part of the activity of the Stonehaven and District Community Council (SDCC). SDCC is a consultee for any new developments that affect Stonehaven and has raised the concerns that form the basis for the work covered in this paper.

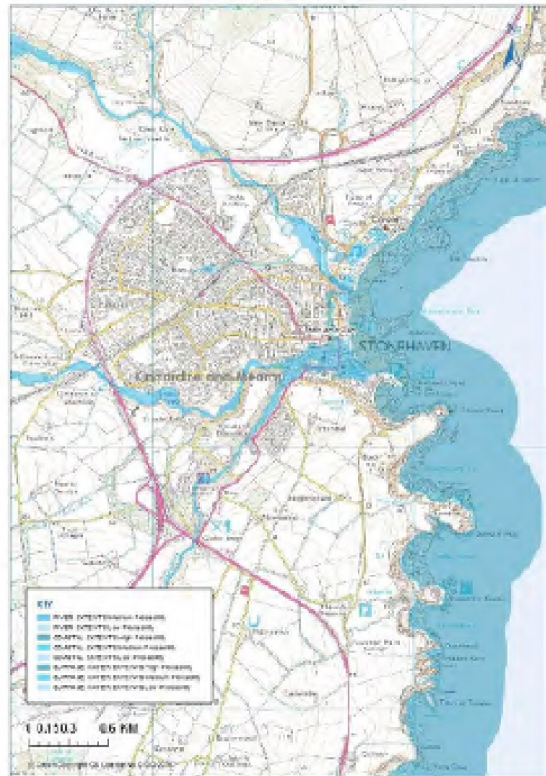


Figure 3: Stonehaven and flood risk. Source: Aberdeenshire (2016c).

2.3 The planning process and flooding

2.3.1 Role of the Developer

Clearly, the developer's role is to maximise his financial returns for stakeholders and so the most economic SUDS are likely to be applied. These may or may not reflect the wider impacts on floodplains or downstream properties and residences when only impacts local to the proposed site are considered. Also, SUDS techniques that can attenuate rainfall at site, e.g. green roofs are rarely used in Scotland as they add to load upon the roof structures of buildings and increase construction costs. If they are used, it is usually for environmental or aesthetic reasons and not for flood risk management purposes.

2.3.2 Role of SEPA in flooding - Coordination with river basin management plans

The key legislation underpinning the SUDS requirement is the transposed EU Water Framework Directive (2000/60/EC, WFD), which is enacted in Scotland via the Water Environment and Water Services (Scotland) Act, 2003 and the Water Environment (Controlled Activities) (Scotland) Regulations 2011, which focus on improvement to ecotoxicological and chemical water quality in a river basin. The Flood Risk Management Act, 2009 (FRM), also gives responsibility for regulating flood risks to the Local Authority. As the number of developments using SUDS has increased in Scotland; and in the UK generally, two key pieces of guidance to developers in the assessment and design of SUDS have emerged; the SUDS Manual (CIRIA,

C753, 2015: superseding, C697, 2007) and Sewers for Scotland, 3rd edition (2015) which prescribe the minimum requirements for flood risk assessment (Table 3).

Table 3: Required elements of a Flood Risk Assessment (SEPA, 2015)

SEPA and the Lead Local Authorities work closely together and with stakeholders to ensure consistency between the Flood Risk Management (FRM) Strategies, Local FRM Plans and the river basin management plans.

2.3.3 Scottish planning process, flood authority

Providing plans for flood risk management has been a mandatory requirement for planning applications in Scotland since 2003. These plans include surface drainage and sustainable urban drainage system (SUDS) design, taking into account the impact of the proposed development upon the natural drainage local to and downstream from the development. This includes whether access is available to existing surface drainage, which is managed by Scottish Water.

Based on hydrological data for the area around a site (SEPA, 2016) schemes are required to attenuate rainfall to no more than natural flows for the 30 year return period and to consider impacts from 100 year and 200 year return period events. The current guidance also asks for the addition of 30% to calculated volumes to account for climate change impacts (CIRIA, C753, 2015); an additional 10% above the previous guidance. Ten per cent extra volume must also be added for any site that might incur future urban sprawl impacts.

2.3.4 Statutory duties of flood authority

FRM LAGs (Local Authority Groups) have a specific role to provide advice on the coordination between flood risk management planning and other relevant plans and policies; particularly river basin management planning. The FRM Act 2009 requires consistency and coordination between river basin management planning and flood risk management planning. River basin management planning takes a catchment based approach to improve the quality of Scotland's waters. Linking the two planning processes is intended to identify areas with potential WFD management needs. Areas for coordination include, for example, promoting land management measures that deliver both flooding and environmental benefits and ensuring that flood defences are designed in a way that causes least environmental damage. June 2016 was the deadline for completion of the first FRM plans.

The Local Authority planning department considers planning applications based on a range of factors that are subject to local and regional strategic development plans. These include:

economic and social developments, transport system developments and renewals, environmental impacts, impacts on trade in existing areas of commerce, shopping and leisure. The consideration of flood impacts, although a statutory duty of the local authority, relies upon the developer's plans, which are usually designed with the assistance of hydrological and hydraulics consultants, who use a range of different design tools and techniques, leading to inconsistency in approach and outcomes for flood risk management.

3. Results and Discussion

The review of planning regulation and statutory duties of different stakeholders above indicates that there is a clear need for regulation that sets out the procedures to be followed and audit to be used during the process of planning and reporting of all hydrology-related works to ensure that the flooding risk is correctly identified, reported, and managed. The purpose of such regulation would be to provide a clear and consistent framework for recording the management of flooding risk for each planning application or proposed development throughout the life of the project. This regulation framework would be applicable to each project that involves activities that may pose flooding risk to the development, general public, and assets or in the vicinity and/or downstream of the proposed development.

To illustrate the application of the proposed methodology in a flood prone area, three representative case studies have been selected for which the 'in principle' planning applications have been reviewed in line with the IHA requirements relevant for the planning application stage.

3.1 Case studies

3.1.1 Case 1

The proposed development is an 'in principle' planning application for construction of a supermarket with petrol station on predominantly hard standing. The site is located in the north part of Stonehaven, close to the River Cowie, which is at risk of flooding together with its tributary, the Megray Burn. The river Cowie flows adjacent to the proposed development, under few local roads, through Stonehaven town centre and into the sea. The site is located adjacent to a major highway development scheme. The developer proposes the use of SUDS for surface water runoff and interaction with the highway development scheme. A connection to Scottish Water supply and drainage network is assumed.

The review of the submitted documentation showed that the key assumptions were acceptable and sufficiently robust for this stage of planning application. The site specific SUDS proposal

was deemed adequate for this stage of application. However, full site investigation for soil classification/description, ground water level determination/ monitoring and any subsequent measures to improve drainage of the soils on site was lacking and would be recommended for inclusion in the later stages. This investigation should include confirmation of the location, operability and condition of the existing drainage system on site and its connection to Megray Burn in order to more accurately assess the risk of flooding. Due to the envisaged interaction with the highway scheme it was recommended that the developer liaises with the relevant authority before finalising their drainage design, especially to confirm the validity of the assumptions made in the FRA and DIA and the potential for flooding downstream in case of failure of the proposed drainage systems for both supermarket and highway developments. The developer should also liaise with the local transportation authority to confirm the local road drainage network can cope with the risk of the potential overland flow on the access roads to the new proposed development.

Table 4: Case study 1 - IHA analysis

It was recommended that the FRA and DIA should be revised prior to submission for the next stage of planning application to incorporate any changes based on the above liaison. The developer should seek confirmation for the assumption of permission to connect to the public network for both water supply and foul drainage from Scottish Water. Details of the full drainage system for surface water disposal (SUDS) together with its management responsibilities should be supplied at a later stage. At detail design stage, the SUDS modelling should be made compliant to C753 SUDS Manual (3rd ed., 2015) to include 30% increase due to climate change. A detailed Drainage Impact Assessment should be submitted a later stage and should include a detailed hydrodynamic model of the cumulative impacts of the proposed and any other adjacent developments (e.g. the highways scheme) on the structures and properties downstream. Special focus should be given to the impact of the proposed developments on the flows through the modified sections of Megray Burn (culverts and modifications due to highway works) as well as the impact on the properties within Stonehaven. Owing to the potential effects of the drainage construction works on the environment, including soil, ground/surface water, flora and fauna, an Environmental Management Plan including a Construction Method Statement should be also submitted at a later stage.

3.1.2 Case 2

The proposed development is an application in principle for construction of a supermarket with 50-bedroom hotel and a restaurant on predominantly hard standing. This application is concurrent with the application described in Case 1. The site is located in the north part of Stonehaven, close to the River Cowie, which is at risk of flooding. The developer proposes the

use of SUDS for surface water runoff and a connection to Scottish Water supply and drainage network is assumed.

Similarly as in Case 1, the key assumptions used were found acceptable and sufficiently robust for this stage of planning application. The site specific SUDS proposal was deemed adequate for this stage of application. Details of soil classification/description, ground water level determination/ monitoring, and any subsequent measures to improve drainage of the soils on site were lacking and a full investigation was recommended for the later stages. Also, permission for connection to Scottish Water supply and drainage network was missing and it was recommended to have it obtained at a later stage.

The full drainage system for surface water disposal (SUDS) together with its management responsibilities would not be required at this stage but should be supplied at the full planning application stage. The SUDS modelling was not compliant to C753 SUDS Manual (3rd Ed, 2015) i.e. did not include 30% increase due to climate change. It was recommended that a detailed Drainage Impact Assessment should be submitted at a later stage and should include a detailed hydrodynamic model of the cumulative impacts of the proposed and any other adjacent developments on the structures and properties downstream. Similarly as in Case 1, it was recommended that an Environmental Management Plan including a Construction Method Statement should be submitted at a later stage in order to capture the potential effects of the drainage construction works on the environment including soil, ground/surface water, flora and fauna.

Table 5: Case 2 - IHA analysis

3.2.3 Case 3

This 'in principle' planning application is for a mixed use development on land to the south-west of Stonehaven, which is currently under agricultural use. The proposal is for a mixed use residential development and retail space with associated landscaping, a bridge over a major road on a site extending to 64 ha. The proposed development is located in the River Carron basin which is at risk of flooding throughout its flow through Stonehaven.

Table 6: Case 3 - IHA analysis

The key assumptions used, including the site specific SUDS proposal, are acceptable and sufficiently robust for this stage of planning application. Only limited ground investigations have been carried out prior to the application and a full site investigation for soil classification/description, ground water level determination/ monitoring, and any subsequent

measures to improve drainage of the soils on site was recommended. Similar to the other case studies, it was recommended that the developer should seek confirmation for the assumption of permission to connect to the public network for both water supply and foul drainage from Scottish Water if a planning consent is granted. Also, the developer should seek confirmation for the assumption of adoption of the road drainage network from the local authority if a planning consent is granted. Details of the full drainage system for surface water disposal (SUDS) together with its management responsibilities should form part of the full planning permission application. The SUDS modelling should be made compliant to C753 SUDS Manual (3rd Ed., 2015) to include 30% increase due to climate change. A detailed Drainage Impact Assessment should be submitted at a later stage and should include a detailed hydrodynamic model of the cumulative impacts of the proposed and any other adjacent developments on the structures and properties downstream.

Specific to this case study, it was recommended that the detailed DIA should include the details of the proposed crossing of the Carron and all culverts with hydrological modelling/calculations demonstrating no adverse effects of the development (incl. culverts/crossings) on the hydraulic regime in the Toucks Burn (tributary), the Carron and the properties downstream of the development. Owing to the potential effects of the drainage construction works on the environment, including soil, ground/surface water, flora and fauna, an Environmental Management Plan including a Construction Method Statement should be submitted at a later stage and should include details of the potential of fluvial and pluvial flooding on the design, construction and maintenance of any new culverts/bridges in terms of sedimentation and blockage. It was recommended that the Construction Method Statement should include fully developed details of the flooding mitigation measures during the construction phase.

3.1.4 Summary of case study findings

Table 7: Case study summary findings

While there seemed to be consistency in the general approach to flood risk and management at the initial planning application stage in terms of completeness of documentation, there was a lack of consistency in the methods of detailing the assumptions forming the basis of the calculations; for example, the assumption of rainfall values, runoff values and soil permeability/type. Similarly, the detail and justification for adoption of the key parameters for modelling was lacking which made the audit more difficult. Acknowledging the fact that the developers would use different software for modelling and calculation and not aiming at a prescriptive approach, the IHA framework would include a requirement to detail the key assumptions and include a justification for adoption of the parameters affecting the calculation of runoff and capacity. With this, the potentially difficult validation of the assumptions due to use

of different software can be avoided and the potential for large differences due to different source assumptions used (e.g. 20% vs 30% climate change) will be minimised. Similarly, the IHA procedure would recommend that a minimum level of ground investigations is carried out prior to the application in principle in order to determine the soil parameters relevant to calculation of runoff and drainage. Also, a dialogue with SW would be beneficial at an early stage, perhaps through the Local Group, in order to validate the assumptions of adequate capacity and permission to connect to SW network.

In the current planning setup, the Flood Authority should ask for IHA from the developers and should share the IHA results publicly, most importantly with the statutory consultees such as the Community Councils and SEPA in order to improve the level of trust the residents have in the current risk management procedures. Such measures would likely result in decreased complaints and claims against the Local/Flood Authority. Similarly, any objections from SEPA (technical adviser and statutory consultee with respect to flooding measures and regulator for WFD considerations regarding water quality impacts) will focus on environmental and water quality issues and less upon hydrogeological issues and where drainage from a site feeds to, which falls under the remit of Scottish Water. IHA would help SEPA to make decisions regarding any environmental impact assessments and mitigating measures if they regard them as unsafe, or insufficient to protect the environment as a statutory consultee. Other statutory consultees, such as RSPB, Historic Scotland and NGOs would benefit from the more focused hydrogeological data that the IHA could provide, which would strengthen objections to unsafe developments that have failed to mitigate future flood risks. This will in turn reduce insurance costs, protect property values, and community and socio-economic risks when new developments are planned in floodplains.

3.2. Potential application of an independent hydrological audit (IHA) throughout the planning process

The proposed IHA can be used as a planning tool to ensure that hydrological risk is managed if it is applied throughout the lifetime of a scheme. It could be applied to all schemes which involve construction activities and which may pose a risk of flooding to the general public, the Developer, the Flood Authority and/or their assets. The audit could be applied as a series of steps at key stages of a project development. These can be related to the four key stages of decision making process within the lifetime of a scheme, equivalent to best practice documentation in other areas of construction risk management (e.g. HD22/08, Scottish Government, 2008). These stages reflect the major parts of the overall project procurement process and are arranged to be an integral part of the overall project progression to ensure the procurement of the hydrological information necessary to undertake an accurate assessment of project risks. The first stage would be the 'in principle' planning application when the IHA would

be applied as demonstrated in the above case studies. The other potential key stages and IHA requirements are listed in Table 8.

Table 8: Key stages on the IHA framework including the envisaged activities and requirements from the Developer.

The IHA requirements at each stage of the lifetime IHA framework would intend to incorporate interdisciplinarity in terms of covering the flood-related aspects of environmental, geotechnical, and hydrological engineering while using modelling/forecasting within a risk assessment framework. The output of this service which would be periodically assessed throughout the lifetime of the project would be to establish a more accurate representation of surface water impact from developments through the use of adequate green/ blue infrastructure and provide a greater assurance to the communities at risk of flooding.

The project lifetime IHA framework (Table 8) indicates that an increasing level of detailed analysis of likely flood impacts, ground conditions, and hydrogeological risks would be required as the planning process proceeds. In addition, a justification for assumptions made in drainage and flood risk assessments and SUDS designs that provide consistency across planning applications would be needed. Finally, it will be crucial that the effect of cumulation of proposed new developments and potential downstream flood risks is considered and managed. This would particularly be true for Stonehaven, where coastal floods that could exacerbate surface flooding impacts are prevalent.

During the project lifetime, the key resources should be the Statutory Body's Flooding Officer (FO) and the Developer's Flood Risk Advisor (FRA) who would work at the interface between the client and statutory body and would establish effective liaison at the earliest stages of project development. With this, the statutory body would be able to meet the planning system requirements for promotion of the protection and improvement of the water environment (rivers, lochs, estuaries, wetlands, coastal waters and groundwater), while also seeking to protect soils from damage such as erosion or compaction before, during, and after construction of new developments. To be effective in terms of reducing risk and identifying opportunities, the IHA procedure would start as soon as possible following project initiation. Following the identification of flood risks in the Flood Risk and Drainage Design reports, a flood risk register would be prepared and submitted as part of the 'in principle' application. This register will be further developed and refined as the project progresses.

4. Conclusions

Climate change has the potential to substantially affect the effectiveness and lifespan of infrastructure under and after flooding. One way to combat this is to address the present and future negative impacts of climate change through adaptation of the infrastructure and the process of planning. This would require building on the shift from reactive management to an anticipatory, pro-active approach that secures the robustness and resilience of infrastructure through the implementation of planned adaptation measures. Despite notable progress in recent years (Boyle et al 2013), many adaptation responses remain elusive or underutilized and investment decisions are not yet being substantially driven by the need to reduce vulnerability to the impacts of climate change. Adapting to climate change is critical to avoid breakdowns in services delivered by infrastructure during and after flooding, as well as to ensure resilience in the face of more incremental and cumulative impacts of both climate change and concurrent developments in the same catchment.

There is a need for a consistent approach to managing the risks of flooding during the planning process, especially at the early stage ('in principle' planning permission) when the opportunities for change are the greatest. This study proposes a framework for an Independent Hydrological Audit during the initial planning application stage, aimed at providing this consistency. It is also intended to ensure that both local and downstream flood risks can be managed in order to protect all properties in the floodplain from the flood itself, as well as preventing the loss of property values, inability to insure against flood and the emotional stresses of displacement and loss of community amenities. The framework reflects the most common procurement methods for planning, design, and construction (Scottish Government, 2013). It also acknowledges the need to encourage innovation and creativity at an early stage of project development i.e. providing 'value for money' which has become more important in many spheres of construction in the last five years (Thomson et al., 2014).

Applied to real-life case studies in North East Scotland, this study showed that increasing levels of communication and cooperation are needed from a broad spectrum of stakeholders who will have to be engaged in the process in order to manage the flooding risk through the planning application process. Efficient communication and dissemination of the findings from the reports and audits will not only aid the management of flood risks, but also enable learning from the past projects and application of this learning into future projects across the range of stakeholders involved (Mickovski 2013; Thomson et al 2014).

The proposed IHA can be expanded from the initial stage ('in principle' planning application) to cover the project lifetime. The procedures should be applicable to all projects promoted by the

Statutory Body where they are responsible for procurement of both the design and construction, projects promoted by the Statutory Body where the design and construction procurement is the responsibility of a Third Party, the parts of projects promoted by a Third Party, where they adjoin or otherwise affect the Statutory Body's assets, planning applications/projects referred to the Statutory Body for direction, where they adjoin or otherwise affect an asset under the jurisdiction of the Statutory Body. This wide application will give the Statutory Body an overview of the concurrent applications and construction, which is essential for management of the flooding risks to residents and infrastructure especially downstream of the developments.

The IHA reports from various stages of the project can be used to fulfil the requirements of the CDM regulations (Health and Safety Executive, 2015) as they will document the residual project Health and Safety risks and the methods employed to manage these. The IHA reports would be included the tender documentation, the pre-construction information and construction phase plan. They will, subsequently, form part of the Health and Safety File for each project thus providing an insight into the flood risk management throughout the life of the project. If adequately recorded over a longer time period, it can also form part of the building information modelling (BIM) process (Tawelian and Mickovski, 2016).

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Figure captions

Figure 1: Map of Scotland showing boundaries of the three regions (North, West and East Scotland). Source: SNIFFER (2016)

Figure 2: Sources of flooding in Scotland (Aberdeenshire, 2016)

Figure 3: Stonehaven and flood risk. Source: Aberdeenshire (2016c)

Table captions

Table 1: Changes in precipitation across Scotland since 1961.

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Table 1: Changes in precipitation across Scotland since 1961.

	% Change in average precipitation since 1961			
	North Scotland	East Scotland	West Scotland	Scotland
SPRING	16.2	9.4	17.3	14.8
SUMMER	-7	0.2	7.3	-0.6
AUTUMN	5.3	22.2	5.9	9.1
WINTER	68.9	36.5	67.3	58.3
AVERAGE	21	18.4	23.3	21.1

Source: SNIFFER (2016)

Table 2. Historic flooding events in Stonehaven since 2008

Date	Watercourse	Settlement	Type of flooding
January 2008	N/A	Stonehaven	Coastal
December 2008	N/A	Stonehaven	Coastal
December 2008	N/A	Stonehaven	Coastal streams and minor watercourse
November 2009	River Carron	Stonehaven	Coastal streams and minor watercourse
Various 2009	N/A	Stonehaven	Coastal
December 2012	N/A	Stonehaven	Minor watercourses and other
July 2012	N/A	Stonehaven	Minor watercourses and other
December 2012	River Carron, Glaslaw Burn	Stonehaven	Minor watercourses and other
December 2012	N/A	Stonehaven	Coastal

Table 3: Required elements of a Flood Risk Assessment (SEPA, 2015)

Element	Information to include in FRA
Source/type flooding	identification of potential flooding sources, i.e. riverine, coastal, pluvial, or combinations of these impacts
Appropriate design flows	Assessment of the appropriate design flows and levels at the site. Sufficient information should be provided to audit derivation of design flows and hydraulic models
Plans of the site	Extent, depth and any flood flow pathways should be indicated on a scale map of the site for the appropriate return periods. Cross sections of the site showing finished floor levels, access routes or other relevant levels, relative to the source of flooding and anticipated water levels for associated probabilities
Rate of inundation	Assessment of the likely rate or speed with which inundation might occur, the order in which various parts of the site or location might flood and the likely duration of floods. Safe access/egress routed to be provided, with likely levels of flooding that might be encountered on these routes. Confirmation of maintenance of routes during the flood event also to be provided.
Plans of new structures	Plans and description of any structures (culverts, screens, embankments or walls, overgrown or collapsing channels, etc) which may influence local hydraulics, and a summary of the findings of any hydraulic modelling including how structures impact water levels on site.
Culverts	If culverts cause a significant flow restriction, levels and discharge rates at which flow would overtop the structure should be identified. Likely impacts of blocked culverts also need to be identified.
Hydraulics	As assessment of the hydraulics of all watercourses, drains or sewers, existing or proposed on the site during flood events to assess the risks of secondary flooding.
Climate change	Best estimates of the impact of climate change on the probabilities, flood depths and extents for both fluvial and coastal situations.
Mitigation measures	Details of flood mitigation measures/strategies to be employed. in the case of ground raising, estimates should be made of the volumes of water which would be displaced from the site for various flood levels following the development of the site. Details of how compensatory flood storage would be implemented.
Displaced water	An assessment of the likely impacts of displaced water on neighbouring or other locations, which might be affected subsequent to development - this applies also to coastal locations.
Ecology	A brief assessment of the potential impact of any development on fluvial or coastal ecology, habitat or morphology and the likely longer

	term stability and sustainability, including WEWS Act requirements
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Table 4: Case study 1 - IHA analysis

Type of data	IHA check	Data submitted for planning
Key stage 1 1.Completeness and appropriateness	<p>Information suitable to stage of planning. M30 design and consideration of M200 events as required.</p> <p>For later stages of planning - attenuation calculations for car parks and plan showing overland flows during the 1:200 event required. Justification of outflow and storage volumes also needed. Designs for detention pond anticipates much greater runoff over 4 hours (M30) and 6 hours(M200) than from WRC and Sewers for Scotland 3 guidance, but these seem to be acceptable as WARP and SOIL figures are chosen conservatively to reflect soil findings on site.</p>	<p>Rationale based on SEPA Guidance Note 8, SUDS for Roads, NESFLAG and CIRIA C697. Soil not suitable for infiltration and will require further exploration. SEPA conditions do not consider water quantity aspects, only water quality. DIA shows general south easterly flow of surface water from new development – and capture into existing drain, which goes under AWPR planned detention ponds and needs to be preserved.</p>
2.Assumptions	<p>CIRIA C697 is not the current SUDS guidance. This had been superseded by C753 (2015) which requires 30% allowance for climate change, not 20%. In addition, 10% to be added for urban sprawl coverage.</p>	<p>Two levels of treatment to be provided for road and parking surface water and one for roofing runoff via a detention tank. Road and parking to have permeable paving with discharge to a sub-storage tank.</p>
3.FRM	<p>Cumulation of flood issues from other developments in the same catchment, e.g. AWPR road nearby needs to be considered. Indication in SEPA maps/local data that there has not been flooding at the site in the past is not a guarantee that cumulation will not cause flood risk in future.</p>	<p>Permissions will be needed from Scottish Water for surface and sewer discharges from petrol station areas to discharge via oil separators. The receiving water for treated surface water may be affected by other local new developments (e.g. AWPR) and this needs to be checked at later planning stages.</p>

Table 5: Case 2 - IHA analysis

Type of data	IHA check	Data submitted for planning
Key stage 1 1. Completeness and appropriateness	This document cannot be acceptable in lieu of Drainage Strategy or Drainage Impact Assessment because it does not really include impact downstream (local and in town) and does not include any mention of former contamination.	Application seems to include 3,750m ² Supermarket, 50 Bedroom Hotel, Restaurant, but the size of the development cannot be verified (no drawings or description) nor does this document mention any of these additional structures. No cumulative effect of adjacent development(s) taken into account.
2. Assumptions	Flood Risk Assessment implicitly covered in this report – probably ok as for a planning permit in principle. Council to confirm 1:30 event is basis for design of SUDS (especially at 1:30 for design SUDS should be designed for 24 hour retention. NB: 1: 200 is only modelled for 16 hours) and 8% for greenfield 1-hr rain runoff calculations. Reference made to Flood Studies Report which is not provided. This is WRC guidance on flood facilities design.	The Proposal is for private factor management of surface water before discharging into local watercourse (Cowie), which lies 10m below site level. What about waste water? Discharge consent may be needed depending upon Class of river.
3. FRM	Surface water flooding – high risk around two smaller regions within site. Discharge not into SW system but directly into Cowie water. What about wastewater, in general and from detention ponds, if designed for 1:30 return period (is this historical 30 year or with climate change impact?) Drainage of groundwater (land drains). Why is there ponding if all granular materials? Can SUDS ponds be effectively used? Where are they located – no plan included. Photographs and text note steep slope towards Cowie, albeit not visible. If there is flooding in the Cowie, slope stability should be checked under hydrodynamic conditions. Erosion and sediment transport downstream should be evaluated using hydrodynamic modelling. This might affect flood	Site walkover in May 2012 – verified no changes, but requires more detail for later stages of analysis, including level differences across site and potential for drainage into the quarry? Site not shown/marked on Fig 1 Fluvial flooding not an issue – river below site level, however local and town downstream effects not considered. SEPA objects to any waste water not discharged within Scottish Water network – where is the waste water going to be discharged to? Drainage Strategy or Drainage Impact Assessment needs to be included in some form during this stage with details provided for the actual planning application. Environmental Management Plan and Construction Method Statement need to be included in some form here and detailed in the actual planning application. No discussion of other environmental aspects that could be affected by the development nor mitigation

	<p>impact in town due to deposition at lower velocities downstream of site blinding river bed.</p> <p>Risks to and from landfill site pertaining to movement of ground/surface water and non collusion compatibility of drainage arrangements with landfill should be detailed somewhere.</p>	<p>measures to protect them – assuming only water impacts downstream, i.e. erosion, sedimentation and flooding</p> <p>No comment on the potential downstream effects.</p>
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Table 6: Case 3 - IHA analysis

Type of data	IHA check	Data submitted for planning
Key stage 1 1.Completeness and appropriateness	DIA, FRA, SUDS and foul water assessments submitted are appropriately detailed and suitable for an 'in principle' planning application. Watercourse engineering and construction phase sections are exemplary in terms of level of detail and consideration to be given to the respective issues at this stage of the planning application.	NESFAP, PAN61 and CIRIA C697 used for design of SUDS. Roads and residential streets to have 2 levels of treatment, as per SEPA note 8 (WAT-RM-08) for developments of more than 100 properties. Likewise for community and employment facilities Drain by gravity to a wastewater pumping station on the site. A new rising main will be needed to take wastewater to the local WWPs. There is capacity at the local WWTW.
2.Assumptions	Soil deemed unsuitable for infiltration systems, which is confirmed by in situ testing. Different levels of treatment needed for different parts of the site because of this. Assumption that SW will allow connection to the public network and will maintain both the water supply and foul drainage. Assumption that road gullies and filter trenches/enhanced swales will be adopted/maintained by the local authority. SUDS based on 1:30 event with extra volume for 1:200 event provided by freeboard and overland flow capacity, which does not fully comply with current guidance (SUDS Manual C753, 2015). However, SUDS design acceptable at this stage.	Assumption that greenfield runoff rates will not be exceeded and that runoff into the Carron will be reduced during extreme storm events. Downstream effects of the proposed development and potential other developments at and/or adjacent to the site have not been detailed.
3.FRM	Method used acceptable and appropriate for this stage of planning. The presented calculations underestimate the potential adverse cumulative impact of concurrent developments at or adjacent to the site.	

Table 7: Case study summary findings

Key stage 1	Case 1	Case 2	Case 3	Data needed
1. Compliance and completeness	Yes	Yes	Yes	Key assumptions OK. Site specific SUDS OK
	Yes	Yes	Yes	Full site investigation required at next stage planning
2.Assumptions	Yes	Yes	Yes	Need to ensure can connect to SW drainage if planning granted
	Yes	Yes	Yes	Need to confirm connection to local authority road drains and capacity if planning granted
	Yes	Yes	Yes	Need to check impact from other local and downstream developments and cumulative impact ref. coastal flooding and socio-economic impacts.
	Yes	Yes	Yes	The SUDS modelling should be made compliant to C753 SUDS Manual (3rd Ed., 2015) to include 30% increase due to climate change and 10% for urban sprawl as required.
3.FRM	Yes	Yes	Yes	Details of the full drainage system for surface water disposal (SUDS) together with its management responsibilities should be supplied at a later stage. Justification of flowrates.
	Yes	Yes	Yes	Detailed DIA should include the details of proposed crossings and all culverts with hydrological modelling/ calculations demonstrating no adverse effects of the development (incl. culverts/crossings) on the hydraulic regime in the receiving waters and properties downstream of the development.
	Yes	Yes	Yes	Owing to the potential effects of the drainage construction works on the environment, including soil, ground/surface water, flora and fauna, an Environmental Management Plan including a Construction Method Statement should include fully developed details of the

				<p>flooding mitigation measures during the construction phase.</p> <p>The EMP should include details of the potential of fluvial and pluvial flooding on the design, construction and maintenance of any new culverts/bridges in terms of sedimentation and blockage</p>
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Table 8: Key stages on the IHA framework including the envisaged activities and requirements from the Developer.

Project stage	IHA activity	Rationale and requirements
Key stage 1: Planning application in principle:	Completeness and appropriateness of submitted documentation in relation to risk of flooding for/to initial planning application stage. The assumptions made within the submitted documentation with respect to flooding. Initial Review of planning application and flooding risks to determine the requirement for detailed flood risk management.	This stage ensures that potential flood risks are identified at project inception. The requirements for specialist hydrological assessments are also assessed at this stage. The document required from the Client/Developer at this stage is an Initial FRM and Drainage Statement
Key stage 2: Full planning application	Completeness and appropriateness of submitted documentation in relation to risk of flooding for/to the full planning application stage. The assumptions made within the submitted documentation with respect to flooding. Preliminary assessment of the accuracy of the hydrological calculations/models	This stage contributes to the preparation of the specimen design and where necessary the requirement for land acquisition. The documents required from the Designer at this stage are the Flood Risk Management Strategy and Drainage Report.
Key stage 3: Design and Construction	Completeness and appropriateness of submitted documentation in relation to risk of flooding for/to the design and construction stages. The assumptions made within the submitted documentation with respect to flooding. Detailed assessment of the accuracy of the hydrological calculations/models.	This stage provides the information for the detailed design and for the contractor to prepare and carry out construction. The output required from the developer at this stage is a detailed Drainage Design and Flood Risk Management Report with all sections completed prior to the construction of relevant areas.
Key stage 4: Post Construction (monitoring)	Completeness and appropriateness of submitted documentation in relation to risk of flooding for/to the post construction stages. The assumptions made within the submitted documentation with respect to flooding. Detailed assessment of the monitoring and interpretation for future hydrological calculations/models.	This stage reports on all construction work and particularly any unexpected ground conditions requiring changes to the drainage design that occurred and any monitoring requirements. The output required from the designer at this stage is the Drainage and Flooding Feedback/Monitoring report.